LEU Fuel Development Progress and Programs, BWXT Technologies, Inc.

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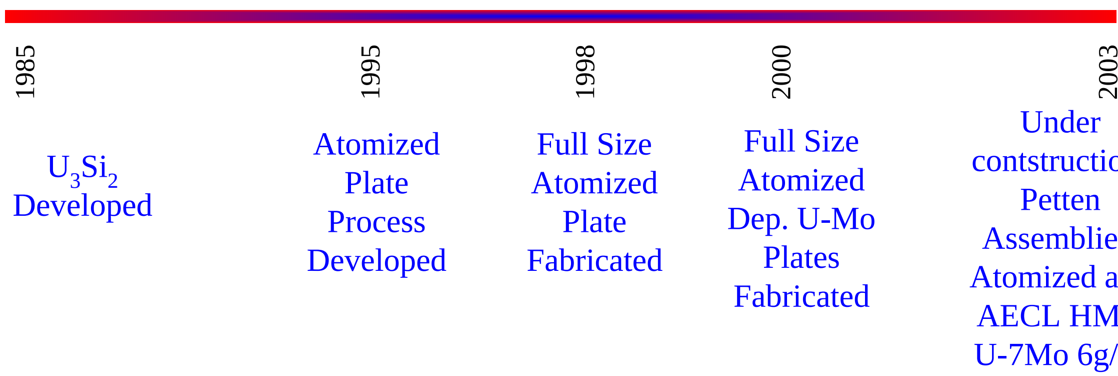
ABSTRACT

BWXT believes that the best method to developing refueling solutions is to completely understand the associated challenges and related requirements. To achieve the maximum fuel densities needed to convert the remaining HEU plate research reactors in the United States, a solid fuel core must be utilized. DOE has mandated that this program be accelerated. During this past year, BWXT has been investigating techniques for fabricating Monolithic (solid core) fuel plates using U-xMo. In cooperation with Argonne National Laboratory, BWXT is preparing a parallel development program utilizing Hot Isostatic Press (HIP) technology, as well as other techniques, to produce a solid fuel core/plate. Diffusion-bonding aluminum presents the challenge. Aluminum rapidly oxidizes and generally requires physically manipulating (hot rolling) the material to break up oxides and allow grain growth. The standard method for fabricating research reactor fuel plates is hot roll bonding. However, hot rolling the differential alloys, aluminum and solid U-xMo foil, has had limited success. The temperature required, above 530C, breaks down the aluminum alloy mandating a solution anneal of the aluminum plate. This is inefficient and has had little success. Extreme processes such as vacuum press and HIP are currently being developed. These methods, showing the most promise, will be discussed herein.

Summary of BWXT Research Test Reactors & Targets Development History

In late 1950, BWXT agreed to participate in the Atoms for Peace proudly proclaimed by President Dwight D. Eisenhower. This program was developed to control the influx of nuclear material and information into the world and hopefully avoid the potential for a catastrophic event. The program was initiated and later BWXT was asked to help develop low-enriched alloys to support converting reactors worldwide. In a field with only two or three vendors, flexibility is key and BWXT accepted the challenge by playing a vital role in developing fuel plate fabrication techniques for high density, low enriched U_3Si_2.

LEU Fuel Development Timeline



BWXT fabricated its first depleted U-Mo dispersion fuel plates in 2000 and is now working with Argonne National Laboratory (ANL) for test in Petten High Flux Reactor (HFR).

Status Of Current Development

BWXT, RTRT, is currently involved in multiple reactor fuel programs and phases of development, all associated with the U.S. Department of Energy reduced enrichment initiatives. One program involves irradiation of two fuel assemblies in HFR Petten in the Netherlands. Each assembly will contain a mix of U-7Mo dispersion powder fuel plates. Each plate will be fabricated with either atomized U-7Mo fabricated by Korean Atomic Energy Research Institute (KAERI) or powder fabricated by Atomic Energy of Canada Limited (AECL). The plates will be alternated in each assembly, ensuring an accurate comparison between the two fuels and minimizing the number of fuel plates to be fabricated from each type of fuel. Delivery of the assemblies is scheduled for 2004.

During the May 2002 Summit between USA and Russia, Presidents George W. Bush and Vladimir Putin agreed to establish a joint-experts group to promote non-proliferation. As a result of that agreement, additional emphasis has been placed on converting U.S. High Enriched Uranium (HEU) research and test reactors. The Advanced Test Reactor (ATR), the University of Missouri - Columbia Research Reactor (MURR), the Massachusetts Institute of Technology (MIT) Test Reactor, the National Institute of Science and Technology Research Reactor (NIST), and the High Flux Isotope Reactor (HFIR) are powered by high-enriched fuel and are not readily convertible using low-enriched U-Mo dispersion fuel. The U.S. made the commitment to convert these reactors at the time the technology became available. Due to the gradient loading, a conversion option for HFIR may be prolonged. Other high-enriched, uniformly loaded research reactors may have a conversion option in the not so distant future.

Monolithic Fuel Development (MFD)

Figure 1 shows the relative U^{235} value for various fuel types. Using a molybdenum alloy requires additional U^{235} to account for the neutron absorption of the Mo. The only full LEU replacement on the chart for the two HEU fuels (HEU UAlx and U_3O_8) at left is the monolithic alloy of U-Mo. This chart demonstrates the relative enrichment between LEU and HEU and how much the alloy has to increase in density to significantly increase the U^{235} content.

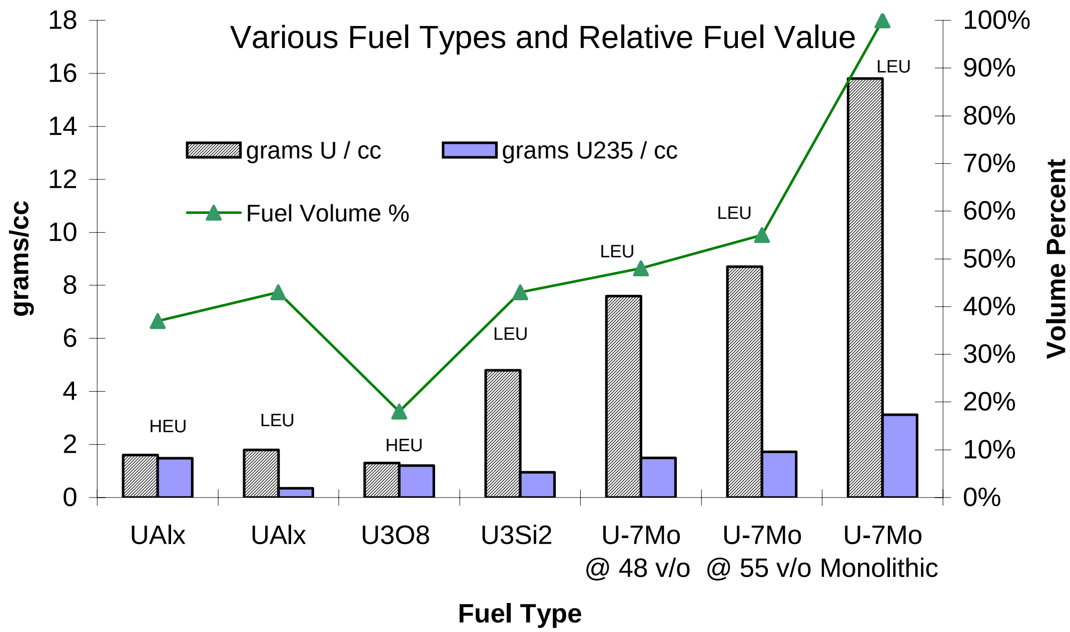


Figure 1

Years ago, solid core fuels were tested and experimented with in various parts of the world. Quite often, the drawback was bonding and the requirement for thick cladding. Recent testing at Argonne National Laboratory (ANL) may have resulted in an innovative method for bonding foils to aluminum cladding, using a method called friction stir welding. The fuel is aptly named "Monolithic Fuel."

BWXT is working in cooperation with ANL to develop fabrication techniques for monolithic fuel. The monolithic fuel design consists of a foil fuel clad in aluminum. The first and possibly largest challenge is bonding aluminum clad to aluminum clad and bonding aluminum clad, to the U-Mo foil. ANL is developing a bonding method using friction stir welding to perform a "planar" type of a weld to the clad and to the foil. ANL is certainly making progress and noting this, BWXT and ANL agree that BWXT should pursue alternative methods in parallel to evaluate multiple fabrication techniques to give the program greater success.

Hot Isostatic Press (HIP) Development

BWXT, RTRT, is in the process of developing a fabrication technique to bond full size research test reactor fuel plates at or near final size using Hot Isostatic Press (HIP). To perform a HIP, the clad-core-clad pack is seal welded and placed inside a vessel. The pressure in the vessel is increased to more than 68 MPa and the temperature is increased to above 450°C. After a predetermined amount of time, the interface surfaces form a bond and the pressure and temperature are reduced. Diffusion bonding across the interface is severely impacted by surface preparation and special emphasis is placed on cleaning and improving these surfaces. After HIP, the plate will be ready to be cold rolled to final size (if necessary) and normal processing will resume.

Monolithic Fuel and Fabrication Processes

A new process does not necessarily mean increased cost. After irradiation testing and fabrication testing, the most important thing is having a viable process that is efficient and reasonably priced. Monolithic fuel requires changing two processes, the powder process becomes a foil process and the traditional fuel plate process changes to accommodate the monolithic parameters. Inspection requirements will certainly change. With a fixed width on the foil, internal dimensions (core width and clad) may only be sampled instead of 100% performed. Top and bottom clad will also be fixed so a reduction of destructive evaluation requirements may also result. Stray particle inspections will no longer exist and homogeneity inspection may become obsolete since the foil thickness is a known value. The actual processes may vary as demonstrated in Figure 2.

RTRT Fuel To Compact (Foil) Processing

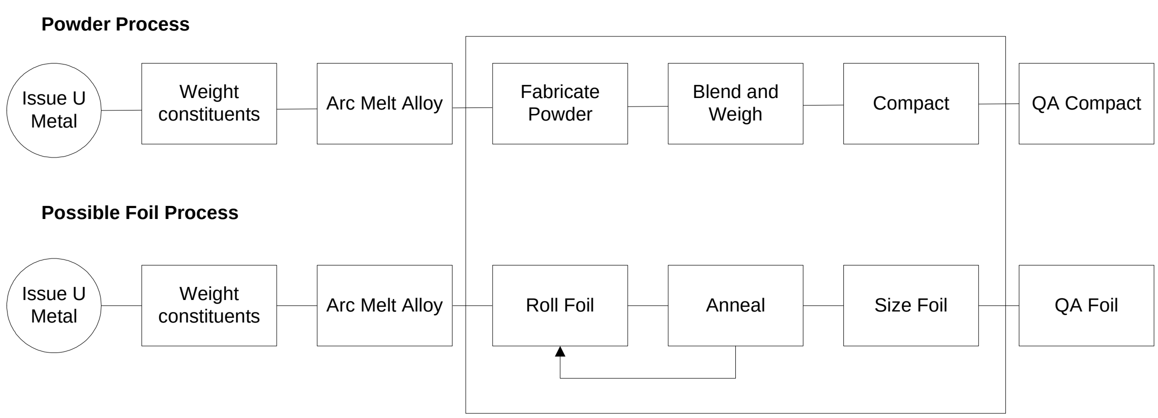


Figure 2

Foil technology is available today. After additional irradiation testing and full-size plate irradiations on monolithic fuels, there is an expectation that the foil fabrication process developed by ANL can be readily scaled up to production. BWXT has the space and resources to construct a manufacturing facility as necessary. The two processes described above could be cost neutral to each other but additional studies will need to be performed.

RTRT Plate Fabrication

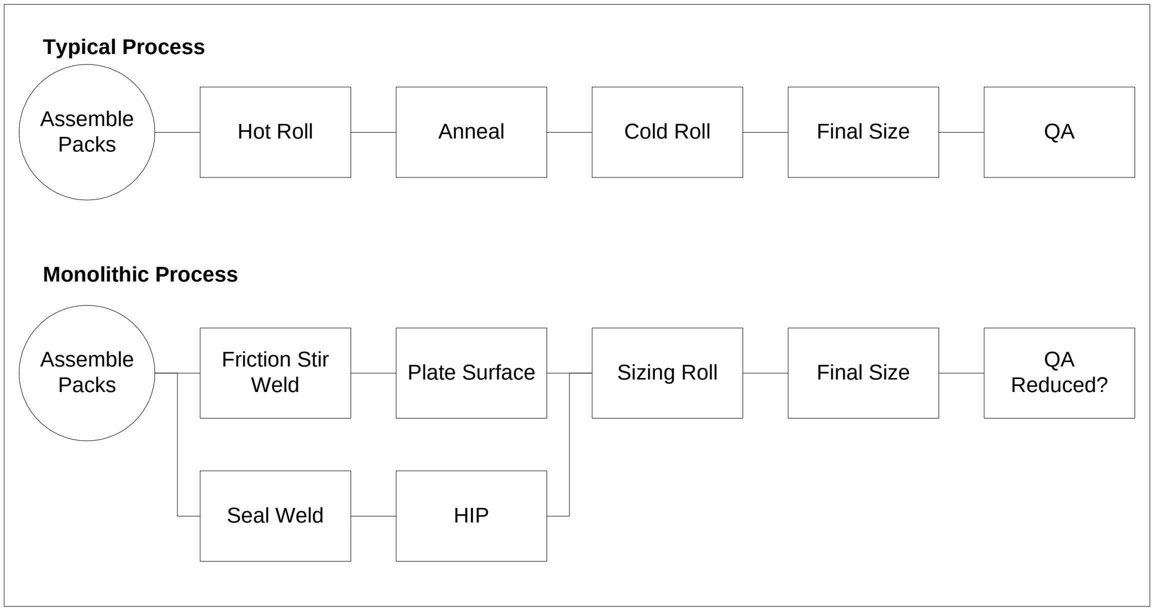


Figure 3

The process for fuel plates is too new to comment on at this time with the exception of saying that the cost will not necessarily increase. Figure 3 shows a generalized chart of a Monolithic fuel plate process. A HIP vessel used could easily be designed to support 50 or even 100 plates per run, greatly decreasing the per plate cost. Friction stir welding is readily automated. Innovation and design of a completely new fabrication process could revolutionize the industry.

Monolithic Fuel Testing

BWXT and ANL have ambitious goals of testing LEU monolithic samples by the end of 2004. Currently, BWXT is HIP testing surrogate materials and plans to be HIP testing depleted U-Mo within 12 months. On a go-forward basis, BWXT will begin testing using LEU by the Fall of 2004.

MONOLITHIC FUEL DEVELOPMENT (MFD) - FORWARD PROJECTION